

Assessment of Human Exposure to Polychlorinated Dibenzofurans and Dioxins

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Fires, explosions and other accidents in polychlorinated biphenyl (PCB)-filled equipment can result in possible exposure of firemen, cleaning personnel and regular workers. Inhalation, dermal exposure and ingestion are the possible routes of exposure. An indirect assessment of the exposure can be made by analyses of wipes, air and water samples and clothes. A direct assessment of exposure can be made by analyses of blood samples, adipose and other tissue samples, feces and bile.

Introduction

The PCB accidents discussed elsewhere in this symposium (1) resulted in a possible exposure of firemen, cleaning personnel and partly also of regular workers. The possible routes of exposure are inhalation, ingestion and dermal. The assessment of exposure can be made from the analyses of a variety of samples like wipes, air, water samples and clothes. These assessments are indirect, as the amount absorbed through the skin is 1 to 10%, via inhalation 50 to 70% and via ingestion 50 to 90%. A direct assessment of the exposure can be made by analyses of samples, e.g., blood, adipose and other tissues, feces and bile, taken from exposed persons.

Indirect Assessments of Exposure

The most important samples for the indirect assessment of exposure are wipe tests. The results from the recent Scandinavian PCB accidents (1) indicate a large variation in the levels of polychlorinated dibenzo-*p*-dioxins (PCDDs) and PCBPs). The isomeric patterns are almost identical in these samples; consequently, the risk of exposure is parallel to the levels found for polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenylenes (PCBPs) (Table 1).

Water was used to extinguish the fire and for washing. Water samples from the Surahammar fire were analyzed (Table 2). A series of PCDFs could be identified in a water sample from the high-pressure washing

Table 1. Comparison of PCDF levels in wipe samples.

Sample	Type	PCDF concn, $\mu\text{g}/\text{m}^2$	Other constituents
Skövde	PCB + oil fire	1	
Surahammar	PCB + oil fire	1-10	
Stockholm	PCB explosion	1.5	PCBPs (major)
Hallstahammar	PCB explosion	1-10	
Imatra	PCB explosion	1-3	PCBPs (minor)
Railway locomotive	PCB explosion	1-100	
Kisa	PCB explosion	1-1000	PCBPs (minor)
Halmstad	PCB explosion	0.1-500	PCBPs (minor)

also containing suspended soot particles. However, when the soot particles had sedimented, the supernatant water phase contained less than 0.1 pg/mL of each PCDF isomer, including 2,3,7,8-tetra-CDF. No solubility studies of PCDFs can be found in the literature, but in laboratory experiments the solubility of 2,3,7,8-tetra-CDD has been found to be 200 pg/mL (2). It can be assumed that the solubilities of PCDDs and PCDFs are quite similar; consequently, the solubility in the washing water is much reduced, possibly due to the adsorption of PCDFs on soot particles.

Air samples have been collected and analyzed in order to estimate the amount of exposure via inhalation. The cartridges used in this study consisted of a filter and a XAD-2 layer; both were analyzed together. Samples were taken during and after the cleaning operations at the Surahammar steel mill and during the cleaning operations of the railway locomotive (1) (Table 3). In Surahammar the levels were below the detection level (2 pg/m³) for each isomer. In a sample collected close to the exploded capacitor of the railway locomotive, the

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Table 2. Analyses of PCDFs in water samples, Surahammar (pg/mL).

Sample	PCDF concn, pg/mL					
	Σ Cl ₄	2,3,7,8-	Σ Cl ₅	Σ Cl ₆	Σ Cl ₇	Cl ₈
High-pressure washing (including soot)	4500	1500	2000	500	15	15
High-pressure washing (after sedimentation)	< 2.5 ^a	< 0.1	< 2.5 ^a	< 1.5 ^a	< 2.5	< 2.5

^a< 0.1 pg each isomer.

Table 3. Analyses of PCDFs in air samples (pg/m³).

Sample	PCDF concn, pg/m ³					
	Σ Cl ₄	2,3,7,8-	Σ Cl ₅	Σ Cl ₆	Σ Cl ₇	Cl ₈
Surahammar (during cleaning)	< 20	< 2	< 10	< 10	< 10	< 10
Surahammar (after cleaning)	< 10	< 2.5	< 10	< 10	< 10	< 10
Railway locomotive (during cleaning)	500	50	50	30	20	20

level of 2,3,7,8-tetra-CDF was 50 pg/m³. No soot was found in this accident.

From the Surahammar fire we have analyzed overalls and underwear. The overalls were washed after use every day. After being used for 14 days an overall was found to have 28 ng 2,3,7,8-tetra-CDF/m² and about 100 ng/m² of all tetra-CDF. Another pair of overalls used and washed for 1 month followed by dry cleaning had almost the same levels. A set of underwear also used for 1 month had less than 5 ng 2,3,7,8-tetra-CDF/m. In order to avoid dermal exposure the workers should be protected by double layers of protective clothing.

Direct Assessment of Exposure

Blood samples have been collected from more than 40 firemen and analyzed by a method described earlier (3). No PCDFs were detected in these samples at a detection level of 0.1 pg/mL blood serum for the 2,3,7,8-tetra-CDF and 1,2,3,7,8- and 2,3,4,7,8-penta-CDFs. We have analyzed a sample of adipose tissue from a man engaged in the clean-up operations in the Binghamton State Office Building. The levels found were 8 ppt of 2,3,7,8-tetra-CDF and 9 ppt for 2,3,4,7,8-penta-CDF, which is close to background levels found in the general population (4).

Check List of Procedure After PCB Accidents

A checklist of procedures to be followed in the event of PCB accidents is given in Table 4.

Table 4. Check list of procedures after PCB accidents.

Information	Workers Industrial hygienists Authorities Occupational Environmental Local medical Press, TV
Coordination	Local coordinator for sampling and cleaning
Sampling	Areas (indoor and outdoor) Exposed personnel (blood) Air Water
Analyses	PCBs Levels and isomeric pattern PCDFs, PCBPs, PCDDs Isomer-specific
Contact	Cleaning firm
Cleaning firm	Experienced Good protection of workers Good equipment Vacuum cleaning, high-pressure washing
Resampling	Contaminated areas, analyses
Waste	Controlled degradation

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